1/27/00                                              37567-X

Applicant   :   M. Nishiguchi et al.

Serial No.:     08/747,910

Filed       :   November 12, 1996

For         :   AUDIO SIGNAL REPRODUCING APPARATUS

Group       :   2747

Examiner    :   F. Isen


EXPRESS MAIL LABEL NO.: EE474773808US



                                    January 24, 2000
                                    1185 Avenue of the Americas
                                    New York, NY  10036
                                    (212) 278-0400


            REQUEST FOR DIVISIONAL APPLICATION
                  UNDER 37 CFR 1.53(b)

Assistant Commissioner for Patents
Box Patent Application
Washington, D.C. 20231

Sir:

     This is a request for filing a Divisional
application under 37 CFR 1.53(b) of pending prior
application Serial No. 08/747,910 filed November 12,
1995, which is a division of application Serial NO.
07/600,818 filed October 22, 1990, now U.S. Patent No.
5,640,458 issued June 17, 1997.

     1.   [x]   Enclosed is a copy of the prior
                application as originally filed including
                a copy of the signed Declaration
                and a copy of the drawings.


     2.   [x]   The prior application is assigned to
                Sony Corporation and the Assignment was
                recorded on        at Reel
                     , Frame        .

3.  [x]   Priority of Application(s) No.(s)
          P278209/89 filed on October 25, 1989
          respectively, in Japan is claimed
          under 35 USC 119.

    [x]   The certified copy in support of the
          claim of priority has been filed in the
          Prior Application Serial No. 07/600,818
          and acknowledgment thereof is requested.

4. [ ]    This is an application of a small entity
          under 37 CFR 1.9(f), and the amounts
          shown below in parentheses apply.
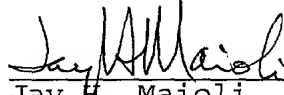
   b. [x] The filing fee is calculated below:

Claims Appearing in the Prior Application,
Less Any Claims Canceled By Amendment Below

|  | Number Filed | Number Extra | Fee |
|---|---|---|---|
| Basic Fee |  |  | $690 ($345) |
| Total claims........ | 5 - 20 = | x | $18 ($ 9) |
| Independent claims... | 2 - 3 = | x | $78 ($39) |

    Fee for Multiple Dependent Claims       $

    Total Filing Fee......................$ 690.00

5.  [x]   The Commissioner is hereby authorized to
          charge any fees which may be required, or
          credit any overpayment to Account No.
          03-3125.  A duplicate copy of this sheet
          is enclosed.

6.  [x]   A check in the amount of $690.00 is
          enclosed.

7.  [x]   Cancel claims 1-3.

8.  [x]   Amend the specification by inserting
          before the first line the sentence:
          --This is a division of prior application
          Serial No. 08/747,910 filed November 12,
          1996, which is a division of Application
          Serial No. 07/600,818 filed October 22,
          1990, now U.S. Patent No. 5,640,458 issued
          June 17,1997.

2

9.  [x]  Incorporation by Reference: The entire
         disclosure of the prior application
         identified above is considered as being a
         part of the disclosure of the accompanying
         application and is hereby incorporated by
         reference therein.

10. [x]  The power of attorney in the prior
         application is to Jay H. Maioli, Reg.
         No. 27,213, Cooper & Dunham, 1185
         Avenue of the Americas, New York, N.Y.
         10036.

a.  [x]  The power appears in the prior
         application.

b.  [x]  Address all future communications to:
         Jay H. Maioli, Cooper & Dunham,
         1185 Avenue of the Americas, New York, NY
         10036.

11. [x]  A Preliminary Amendment is enclosed.

                         Jay H. Maioli
                         Reg. No. 27,213

(212) 278-0400

JHM:dmcd

<u>IN THE UNITED STATES PATENT AND TRADEMARK OFFICE</u>

"Express Mail" Mailing Label No. EE474773808US

Date of Deposit: January 24, 2000

    I hereby certify that this Request For Divisional Application Under 37 CFR 1.53(b), Copy of Specification and claims, Copy of Drawings, a Copy of Signed Declaration, and Preliminary Amendment are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and addressed to the Assistant Commissioner for Patents, Box Patent Application, Washington, D.C. 20231.

TRIN ISCOA

Inventors : M. Nishiguchi et al.

Title    : AUDIO SIGNAL REPRODUCING
            APPAATUS

Serial No.: 08/747,910

JAY H. MAIOLI
REG. NO. 27,213

COOPER & DUNHAM LLP
1185 Avenue of the Americas
New York, NY 10036
(212) 278-0400

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants:    M. Nishiguchi et al.

Serial No.:

Filed        :

For          :    AUDIO SIGNAL REPRODUCING APPARATUS

Group A.U.:    2747


EXPRESS MAIL LABEL NO. EE474773808US


                              January 24, 2000
                              1185 Avenue of the Americas
                              New York, NY  10036
                              (212) 278-0400


PRELIMINARY AMENDMENT

Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

Prior to the initial examination of the above-identified application, which is a Division under 37 CFR 1.53(b) of Application Serial No. 08/747,910 filed November 12, 1996, which is a division of Application Serial No. 07/600,818 filed October 22, 1990, now U.S. Patent No. 5,640,458 issued June 17, 1997, Applicants respectfully request that the application be amended as follows.


IN THE CLAIMS

Please cancel claims 1-3, without prejudice or disclaimer and add new claims 4-8.

--4. (New) A headphone-type audio signal reproducing apparatus comprising:

a user-removable semiconductor memory unit for storing digitized and high-efficiency compression encoded audio data;

a decoder for reading out data stored in the semiconductor memory unit and for decoding the read-out data by performing an inversion of the compression encoding;

a digital/analog converter for converting output signals from the decoder into analog signals;

a headphone unit for receiving the analog signals form the digital/analog converter and converting the analog signals from the digital/analog converter into acoustic sounds; and

a lightweight housing for containing the semiconductor memory unit, the decoder, the digital/analog converter and the headphone unit, the lightweight housing being compact and adapted for placement on a user's head,

wherein the audio data has been compression encoded by dividing input digital signals into a plurality of frequency bands such that bandwidths of the bands are broader for progressively higher frequency bands and each frequency band has a corresponding energy level, setting

2

an allowable noise level on a band-by-band basis in accordance with the energy level of each frequency band, including setting the allowable noise level for a given energy level progressively higher for progressively higher frequencies, and quantizing the components of each band with a number of bits corresponding to a difference in level between the energy of each frequency band and the preset allowable noise level, including adjusting the number of bits allocated upon quantizing according to the allowable noise level, and wherein the decoder performs the inversion of the compression encoding.

--5. (New) The headphone-type audio signal reproducing apparatus according to claim 4, further comprising a battery for powering the decoder, the digital/analog converter, and the headphone unit and being arranged in the housing.

--6. (New) The headphone-type audio signal reproducing apparatus according to claim 4, wherein the headphone unit comprises a left earphone unit and a right earphone unit attached to the housing for placement at respective left and right ears of the user.

--7. (New) The headphone-type audio signal reproducing apparatus according to claim 4, wherein said semiconductor memory unit comprises a semiconductor chip with a playback time of at least 33 minutes.

--8. (New) A method for reproducing audio signals using a portable apparatus comprising the steps of:

storing digitized and high-efficiency compression encoded audio data in a user removable semiconductor memory;

reading out data stored in the semiconductor memory and decoding the read-out data by performing an operation that is an inversion of the compression encoding;

converting digital data output from the decoder into analog signals;

receiving the analog signals from the digital/analog converter and converting the analog signals from the digital/analog converter using an earphone unit into acoustic sounds for listening by the user; and

containing the semiconductor memory, the decoder the digital/analog converter, and the earphone unit in a lightweight housing adapted for placement on a user's head, and wherein the operation of compression encoding comprises the steps of dividing input digital signals

into a plurality of frequency bands such that bandwidths of the bands are broader for progressively higher frequency bands and each frequency band has a corresponds energy level, setting an allowable noise level on a band-by-band basis in accordance with the energy level of each frequency band, including setting the allowable noise level for a given energy level progressively higher for progressively higher frequencies, and quantizing the components of each band with a number of this corresponding to a difference in level between the energy of each frequency band and the preset allowable noise level, including adjusting the number of bits allocated upon quantizing according to the allowable noise level.--

## REMARKS

Claims 1-3 have been canceled, without prejudice or disclaimer, and new claims 4-8 have been added hereby.

This application is a division under 37 CFR 1.53(b) of Application Serial No. 08/747,910 filed November 12, 1996, which is a division of application Serial No. 07/600,818 filed October 22, 1990 now U.S. Patent No. 5,640,458 issued June 17, 1997.

An early and favorable examination on the merits is earnestly solicited.

Respectfully submitted,

COOPER & DUNHAM LLP

Jay H. Maioli
Reg. No. 27,213

JHM:dmcd

TITLE OF THE INVENTION

Audio Signal Reproducing Apparatus

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an audio signal reproducing apparatus and, more particularly, to a small sized audio signal reproducing apparatus in which reproduced audio signals may be heard by a headphone.

Description of the Prior Art

Recently, a small sized audio signal reproducing apparatus, in which audio signals may be heard by a headphone, has become popular to provide for a more extensive range of appreciation of music or the like.

With the small sized audio signal reproducing apparatus for hearing the reproduced audio signals with a headphone, there is a demand for further reduction in size and weight since such reduction possibly leads to more widespread use and mode of application.

However, with the above described small sized audio signal reproducing apparatus, magnetic tapes or optical disks, such as, for example, compact disks, are used as the signal recording media, so that the apparatus in its entirety cannot be reduced in size beyond the size of these recording media. On the other hand, since the mechanical parts for driving the recording media are necessitated, the operational reliability may be lowered due

1

to wear or damage to movable parts. The playback operation may also be affected by mechanical disturbances, such as vibrations. In addition, there is a limit to reduction in size and weight due to the use of an electrical motor or a plunger.

Recently, with the progress in the technique of high efficiency compression encoding of audio-signals, high-fidelity playback sounds may now be produced even at the rate of the order of, for example, 64 kb per second per channel. Among the techniques for such high efficiency compression encoding, there are a sub-band coding (SBC) in which audio signals on the time axis are divided into a plurality of frequency bands prior to encoding; an adaptive transform encoding (ATC) in which signals on the time axis are converted by orthogonal transform into signals on the frequency axis which are then divided into a plurality of frequency bands, and adaptive encoding is performed in each of these frequency bands; and an adaptive bit allocation (APC-AB), which is a combination of the above described SBC and an adaptive predictive encoding (APC) and which consists in dividing the signals on the time axis into a plurality of bands, converting the band signals into base-band signals or low-frequency signals and performing plural order linear predictive analyses for predictive encoding.

For compression encoding of audio signals on the left and right stereo channels, it has now become possible to transmit high fidelity stereo audio signals at the transmission rate in

2

the order of 64 kb per second per channel through the use of the correlation between the left and right stereo signal or the use of codes of unequal lengths.

OBJECT AND SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a headphone type ultra small size audio signal reproducing apparatus in which high quality audio signal reproduction may be achieved with the small data volume through the use of high efficiency compression encoding and a semiconductor memory as a signal recording or storage medium.

For accomplishing the above object, the present invention provides a headphone type audio signal reproducing apparatus comprising a semiconductor memory for storing digitized and high efficiency compression encoded audio signals, a decoder for reading out data stored in said semiconductor memory and decoding the read-out data, by way of performing an operation which is an inversion of compression encoding, a digital/analog converter for converting output signals from said decoder into analog signals, and a headphone unit for converting output signals from said digital/analog converter into acoustic signals.

As a typical example of the high efficiency compression encoding operation, input signal signals are divided into a plurality of frequency bands so that the bandwidths will be broader for progressively higher frequency bands, the allowable noise level is set on the band-by-band basis in accordance with

the energy of each band and the components of each band are quantized with the number of bits corresponding to the level of the difference between the energy of each band and the preset allowable noise level. In presetting the allowable noise level, the allowable noise level is set so as to be higher for the same energy for progressively higher frequencies for minimizing the degradation in the sound quality and reducing the bit rate. In this manner, the requirements for satisfactorily reproducing audio signals with the use of semiconductor memories, that is, the requirements for reproducing so-called high fidelity level audio signals for at least several minutes, may be satisfied.

With the reproducing apparatus of the present invention, which makes use of the semiconductor memory as the signal recording medium, to reduce the size and weight of the apparatus drastically so compared to the reproducing apparatus which makes use of the magnetic tape or optical disk as the recording medium.

That is, since the semiconductor memory is used as the recording medium for high efficiency encoded audio data, not only may the main body of the reproducing apparatus be reduced in size and weight, but the movable parts, such as are necessitated in the conventional reproducing apparatus in which disks or tapes used as recording medium are driven mechanically for reproducing the audio signals, may be eliminated, so that the apparatus superior in service life or in durability may be obtained.

In addition, the masking level is raised for higher

4

frequencies during data compression to reduce the number of bits allocated at the time of quantization to realize the bit allocation suited to the human auditory sense. Thus the degradation in the sound quality may be minimized with the use of a lesser number of bits or a lower bit rate so that the audio signal reproduction may be made satisfactorily with the use of the semiconductor memory chips.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic block diagram showing an embodiment of an audio signal reproducing apparatus according to the present invention.

Fig. 2 is a perspective view showing a typical headphone device employed in the audio signal reproducing apparatus shown in Fig. 1.

Fig. 3 is a block circuit diagram showing a typical high efficiency compression encoding circuit adapted for generating audio data stored in a semiconductor memory.

Fig. 4 is a diagrammatic view showing the critical bands.

Fig. 5 is a diagrammatic view showing the Burke spectrum.

Fig. 6 is a circuit diagram showing a filter circuit.

Fig. 7 is a diagrammatic view showing the masking spectrum.

Fig. 8 is a diagrammatic view showing the minimum audible curve and the masking spectrum synthesized together.

Fig. 9 is a perspective view showing a modification of a headphone device employed in the audio signal reproducing

5

apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

By referring to the drawings, a preferred embodiment of the present invention will be explained in detail.

An audio signal reproducing apparatus according to an embodiment of the present invention and the periphery thereof are shown in a block circuit diagram of Fig. 1.

In this figure, audio data which have been processed by high efficiency compression encoding are stored in a semiconductor memory 41 of an audio signal reproducing circuit section 40. That is, the data stored in semiconductor memory 41 are obtained in such a manner that audio signals are supplied to input terminal 31 and are converted in an analog/digital (A/D) converter 32 into digital signals, these digital signals being then processed in an encoder 33 by high efficiency compression encoding. The data read out from semiconductor memory 41 are supplied to a decoder 42, where they undergo a decoding operation which is an inversion of the above mentioned compression encoding operation. These decoded signals are then supplied to a digital/analog (D/A) converter 43 where they are converted into analog signals, which are then transmitted to a headphone unit 44 so as to be converted into acoustic signals.

In Fig. 2, a head device 5 as a specific example of the headphone unit 44, inclusive of associated parts, is shown. The headphone device 50 is constituted by a band 51, band length

6

adjustment members 52L, 52R, connected to both ends of the band 51, headphone driven units 53L, 53R connected to these adjustment members 52L, 52R by means of connectors and ear pads 54L, 54R mounted on the driver units 53L, 53R.

The circuitry for an audio signal reproducing apparatus is built in the inside of the band length adjustment members 52L, 52R. That is, a memory chip 56 associated with the semiconductor memory 41 is accommodated in the band length adjustment member 52L. This memory chip 56 may be formed as an article of commerce, using, for example, a mask ROM, and put on the market as exchangeable music software goods. In the interior of the other band length adjustment member 52R, there are provided a circuit unit 57 including the decoder 42 and the D/A converter 43 and a so-called button battery or re-chargeable battery 58 which may be used as an electrical power source.

Referring to Fig. 3, a more specific example of high efficiency compression encoding for obtaining audio data stored in the semiconductor memory 41 of the audio signal reproducing apparatus of the present embodiment, will be explained.

Among the high efficiency compression encoding techniques, there are a sub-band encoding (SBC), adaptive transform encoding (ATC) or adaptive bit allocation (APC-AB). With the specific example shown in Fig. 3, an arrangement for improving the compression efficiency further is used.

With the specific example of the compression encoding unit,

7

shown in Fig. 3, the digitized audio signals is divided into
plural frequency bands which will have broader bandwidths towards
the side of progressively higher frequencies. For example, the
input digital signal is divided into plural frequency bands in
accordance with the so-called critical bands or bandwidths, which
take human auditory characteristics into consideration, as will
be explained subsequently. On the other hand, referring to Fig.
3, there are provided a sum detection circuit 14 and a filter
circuit 15 as noise level setting means for setting the allowable
noise level on the band-by-band basis in accordance with the
energy value, peak value or the mean value) of each critical
band, and a quantization circuit 24 for quantizing the band
components by the numbers of bits allocated in accordance with
the level of the difference between the signal energy level of
each band and the level set by the noise level setting means.
The noise level setting means is so constructed that the
allowable noise level will be set to a progressively higher level
for the same energy towards the side of the higher frequency
critical bands to this end, the system of Fig. 3 is so
constructed that an allowance function for setting the allowable
noise level in an allowance function generator 29 controlled by
an allowance function control circuit 28, as will be described
subsequently, and the allowable noise level is set on the basis
of this allowance function. The quantized output from quantizer
24 is subsequently outputted at an output terminal 2 of the

encoder of the present embodiment by way of a buffer memory 25.

The high efficiency compression encoding system shown in Fig. 3 is constructed in accordance with the so-called adaptive transform encoding (ATC) wherein the audio signals are processed by fast Fourier transform (FFT) for conversion of the signal on the time axis into that on the frequency axis, followed by encoding or requantization. In the specific example shown in Fig. 3, bit rate adjustment or so-called bit packing is performed for maintaining a constant bit rate per frame over a predetermined time period.

That is, referring to Fig. 3, audio signals, for example, are supplied to input terminal 1. The audio signals on the time axis are transmitted to a fast Fourier transform circuit 11 where the audio signals on the time axis are converted into signals on the frequency axis at a predetermined time period or at each frame to produce FFT coefficients each consisting of a real number component value Re and an imaginary number component value Im. These FFT coefficients are transmitted to an amplitude phase information generator 12, where an amplitude value Am and a phase value are produced from the real number component Re and the imaginary number component Im. Of these amplitude and phase values, only the data of the amplitude value Am is taken out as output from the amplitude phase information generator 12, since the human auditory sense in general is sensitive to the amplitude or power, but is rather insensitive to the phase, in the

9

frequency domain.

The so-produced input digital data, such as the amplitude value Am, is transmitted to a band division circuit 13, where the input digital data expressed by the amplitude value data Am are divided into a plurality of so-called critical bands. With the "critical bands", the human auditory characteristics or frequency analysis capability are taken into account in such a manner that the frequency of 0 to 10 kHz is divided into 24 bands, or the frequency of 0 to 32 kHz is divided into 25 bands, so that progressively broader bandwidths are allocated towards the side of the higher frequencies. More specifically, the human auditory sense has characteristics comparable to those of bandpass filters with each band delimited by each bandpass filter being termed a critical band. Fig. 4 shows such critical bands wherein, for simplicity sake, these bands are expressed by 12 bands $B_1$ to $B_{12}$.

The amplitude values Am for each of, for example, 24 or 25 critical bands, obtained by band division at the band division circuit 13, are transmitted to the sum detection circuit 14, where the energy or spectral intensity of each band is found by taking the sum of the amplitude values Am in each band or, alternatively by taking the peak or mean value of the amplitude values Am or the sum total of the signal energies. The output of the sum detection circuit 14, that is the spectrum of the sum of the amplitudes, for example, of each bands, is generally

10

termed the Burke spectrum.  Fig. 5 shows, as an example, the Burke spectrum SB for each of the bands $B_1$ to $B_{12}$.

In order to take the effect of the Burke spectrum SB on masking into account, predetermined weighting functions are convolved into the Burke spectrum SB (convolution).  To this effect, the output of the sum detection circuit 14, that is the respective values of the Burke spectrum SB, are transmitted to filter circuit 15.  As shown in Fig. 6, the filter circuit 15 is constituted by delay devices $(z^{-1})$ $101_{m-2}$ to $101_{m+3}$ for sequentially delaying input digital sample data, multipliers $102_{m-3}$ to $102_{m+3}$ for multiplying the outputs from delay devices $101_{m-2}$ to $101_{m+3}$ by filter or weighting coefficients, and a sum circuit 104.  The convolving operation for the Burke spectrum SB is performed by multiplying the outputs of the delay devices by filter coefficients 0.0000086, 0.0019, 0.15, 1, 0.4, 0.06 and 0.007 at the multipliers $102_{m-3}$, $102_{m-2}$, $102_{m-1}$, $102_m$, $102_{m+1}$, $102_{m+2}$ and $102_{m+3}$, respectively.  The sum total of the Burke spectrum for each band and the influence from adjacent bands indicated by broke; ines shown in Fig. 5 is taken by this convolving operation.

It will be noted that, if a level a, corresponding to an allowable noise level for computing the masking spectrum, or an allowable noise spectrum, of the Burke spectrum SB, is low, the masking spectrum or the masking curve descends, with the result that the number of bits allocated at the time of quantization at

11

the quantizer 24 has to be increased. Conversely, if the level α is high, the masking level ascends, with the result that the number of bits allocated at the time of quantization may be decreased. Meanwhile, the level α corresponding to the allowable noise level is such a level as will prove to be the allowable noise level for each critical band as a result of the deconvolution operation, as will be explained subsequently. In general, in audio or the like signals, the spectral intensity or energy is low at higher frequencies. Hence, in the present embodiment, the above is taken into consideration in such a manner that the level α is increased towards the higher frequencies with lesser energy values and the number cf the allocated bits is decreased towards the higher frequencies. Thus the noise level setting means is so constructed that the level α is set to progressively higher values towards the side of the higher frequency for the same energy value.

That is, in the present embodiment, the level α corresponding to the above mentioned allowable noise level is computed and controlled to be higher towards the side of the higher frequencies. To this end, the output of the filter circuit 15 is transmitted to a subtractor 16 which is designed to find the level α in the convolved region. To the subtractor 16 is supplied the allowance function (the function expressing the masking level) for finding the level α. The level α may be controlled by increasing or decreasing the allowance function.

12

This allowance function is supplied from a function generator 29 controlled by a function controller which will be explained subsequently.

That is, the level $a$, corresponding to the allowable noise level, is given by the formula (1)

$$a = S - (n - ai) \qquad \ldots\ldots (1)$$

where i is the number afforded to the critical bands in the order of the increasing frequencies of the critical bands.

In this formula (1), n and a are constants, with a>0, and S is the intensity of the Burke spectrum following the convolution. In the formula (1), (n-ai) represents the allowance function. Since it is more preferred to decrease the number of bits allocated to a higher frequency band with a correspondingly lesser energy value to reduce the number of bits in their entirety, the values of n and a are set in the present embodiment to 38 and 1, respectively (n=38 and a=1) for which satisfactory encoding may be achieved without deterioration in the sound quality.

The level $a$, found as described above, is transmitted to a divider 17, which is designed for deconvolving the level $a$ in the convolved region. Thus the masking spectrum may be found from the level $a$ by such deconvolving operation. That is, this masking spectrum represents the allowable noise spectrum. Although a complicated operation is necessitated for such deconvolving operation, the deconvolving operation is performed

13

with the present embodiment by using the simplified divider 17.

The masking spectrum is transmitted via a synthesis circuit 18 to a subtractor 19, to which the output from the sum detection circuit 14, that is the Burke spectrum SB from the sum detection circuit 14, is supplied by means of a delay circuit 21. Thus the masking spectrum is subtracted at the subtractor 19 from the Burke spectrum SB, so that, as shown in Fig. 7, the Burke spectrum SB is masked at lower than a level indicated by the respective levels of the masking spectrum MS.

The output of the subtractor 19 is supplied to quantizer 24 by means of a ROM 20. In the quantizer 24, the amplitude value Am supplied thereto by means of a delay circuit 23 is quantized with the number of bits allocated in accordance with the output of the subtractor 19. In other words, the components of each critical band are quantized in the quantizer 24 with the number of bits which is allocated in accordance with the level of the difference between the energy of each critical band and the level of the output of the noise level setting means. The delay circuit 21 is designed for delaying the Burke spectrum SB from the sum detection circuit 14 in consideration of the delay caused in each circuit component upstream of the synthesis circuit 18, whereas the delay circuit 23 is designed for delaying the amplitude value Am in consideration of the delay caused in each circuit component upstream of the ROM 20. This ROM is provided for transient storage of the output of the subtractor 19 at a

14

predetermined time interval during quantization for subsequent readout to quantizer 24.

It will be noted that the synthesis in the above mentioned synthesis circuit 18 is performed for synthesizing or combining the data for a so-called minimum audible curve or equal loudness curve RC, characteristic of the human auditory sense, supplied from a minimum audible curve generator 22, as shown in Fig. 8, with the above mentioned masking spectrum MS. By combining the minimum audible curve RC with the masking spectrum MS in this manner, the allowable noise level may be set up to the upper limit of the hatched line zone in Fig. 8, so that it becomes possible to reduce the number of bits for the hatched line zone in Fig. 8 at the time of quantization. Meanwhile, critical bands, similar to those shown in Fig. 4, are shown in Fig. 8, along-with the signal spectrum SS.

The data from the buffer memory 25 are transmitted to a data volume operating circuit 26 to find a data volume which is then transmitted to a comparator 27. In the comparator, the data volume is compared to a desired value of the number of bits per frame supplied from terminal 3 for bit rate adjustment. The result of comparison is transmitted to the above mentioned function controller 28. This function controller 28 controls the function generator 29 to compute the allowance function to find the level a supplied to the subtractor 16. With changes in this allowance function, the masking spectrum MS of Fig. 8 is variable

15

controlled in level. More specifically, the number of allocated bits may be increased or decreased in their entirety by parallel displacement of the masking spectrum MS in the direction of the signal level, that is, vertically in Fig. 8, with the number of bits transmitted during a predetermined time interval remaining constant. In this manner, the function generator 29 generates not only the allowance function for finding the level α but also the function for bit rate adjustment.

With the above described high efficiency compression encoding apparatus of the present embodiment, the allowable noise level is increased towards the side of the higher frequencies with lower energy values to decrease the number of bits allocated for the side of the higher frequencies, so that it becomes possible to reduce the number of bits allocated for quantization.

It will be noted that, in the present embodiment, the above mentioned bit rate adjustment and/or the minimum audible curve synthesis may be eliminated. That is, if the bit rate adjustment is to be eliminated, the data volume operating circuit 26, comparator 27 and the function controller 28 are eliminated and the allowance function from function generator 29 is fixed to, for example, (38-i). If the minimum audible curve is not synthesized, the minimum curve generator 22 and the synthesis circuit 18 are eliminated, so that the output from subtractor 16 is supplied directly to subtractor, 19 after deconvolution at the divider 17.

16

With the above described high efficiency compression encoding, high fidelity audio signals may be transmitted at, for example, 64 kbps per channel, so that audio data about 4 minutes or longer may be stored in, for example, a 16 M bit make ROM chip. If four of such mask ROM chips are arranged as a package, music software goods with a playback time of about 17 minutes may be provided as an article of commerce. Although the playback time may be substantially halved for a stereophonic sound source, the number of bits per channel may be reduced further by taking advantage of the correlation between the left and right channels, so that, by packaging four 16 M bit ROMs, a playback time of about ten and several minute may be realized. In view of the tendency towards a higher integration degree of semiconductor memories, mask ROMs with 128 M bits or 256 M bits would be commercially available in a not distant future. Since further improvement in the high efficiency encoding technique can be reckoned, it would be possible to transmit high quality high fidelity audio signals at 64 kbps per stereo-channel and to provide a one-chip audio signal software article with a playback time of 33 or 66 minutes.

It will be noted that the audio signal reproducing apparatus according to the present invention may be applied not only to the usual headphone device shown in Fig. 2, but to a headphone device 60 in which the headphone driver units are exposed to outside, as shown for example in Fig. 9. With the headphone device 60,

17

shown in Fig. 9, the headphone driven unit 61L, 61R are directly attached in the users' ears, and a main body of the playback circuit section 63 is connected to these driver units 61L, 61R by means of a signal transmission cord 62. The semiconductor memory 41, decoder 42, D/A converter 43 and batteries as the power source, shown in Fig. 1 are accommodated in the main body of the playback circuit section 63. On the other hand, an operational mode selector circuit 64 for controlling the playback operation and a volume dial 65 are provided on the outer surface of the main body of the playback circuit section 63, which may be implemented with the size and the shape of, for example, a pendant.

The present invention is not limited to the above described embodiment. For example, an audio signal reproducing apparatus may be constituted by circuit elements including and downstream of the semiconductor memory 41 in Fig. 1 or may additionally include the A/D converter 32 and the encoder 33. The playback circuit section or the batteries may also be accommodated in a thickened headphone band or in a headphone driver unit. The high efficiency compression encoding may be implemented by, for example, sub-band encoding, instead of by adaptive transform encoding as described in the foregoing embodiment. If such sub-band encoding technique is used, the signal may be divided by, for example, band-pass filters, into a plurality of frequency bands, and the allowable noise level may be set so as to be

18

progressively higher towards the side of the higher frequencies

for the same energy level.

WHAT IS CLAIMED IS:

1.   A   headphone   type   audio   signal   reproducing   apparatus
comprising

    a  semiconductor  memory  for  storing  digitized  and  high
efficiency compression encoded audio signals,

    a decoder for reading out data stored in said semiconductor
memory and decoding the read-out data, by way of performing an
operation which is an inversion of compression encoding,

    a  digital/analog  converter  for  converting  output  signals
from said decoder into analog signals, and

    a  headphone  unit  for  converting  output  signals  from  said
digital/analog converter into acoustic signals.

2.    The  audio  signal  reproducing  apparatus  according  to  claim
1  wherein  the  operation  of  compression  encoding  comprises
dividing  input  digital  signals  into  a  plurality  of  frequency
bands,  so  that  the  bandwidths  of  the  bands  will  become  broader
for  progressively  higher  frequency  bands,  setting  the  allowable
noise  level  on  the  band-by-band  basis  in  accordance  with  the
energy  of  each  frequency  band  and  quantizing  the  components  of
each  band  with  the  number  of  bits  corresponding  to  the  level  of
a  difference  between  the  energy  of  each  band  and  the  preset
allowable noise level.
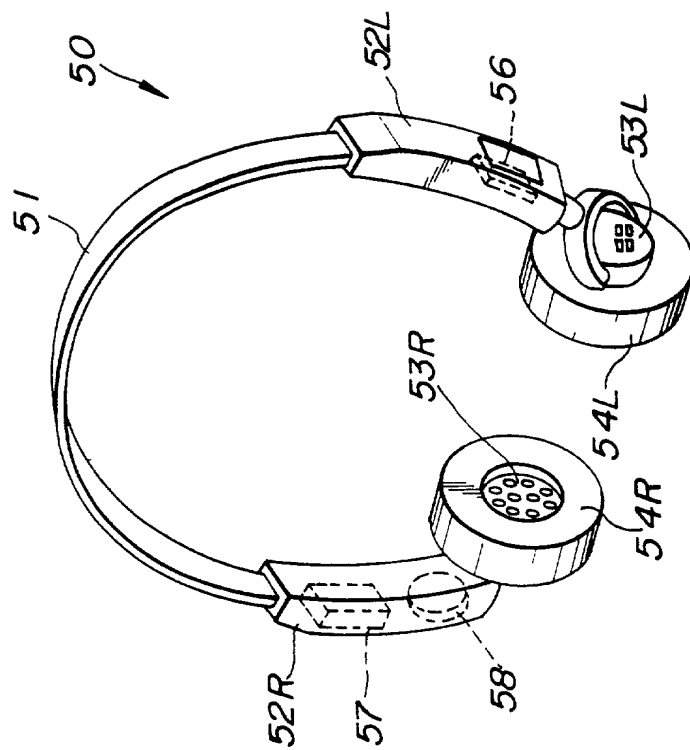
3.    The  audio  signal  reproducing  apparatus  according  to  claim
2  wherein  the  preset  allowable  noise  level  is  set  so  as  to  be
higher  for  the  same  energy  for  progressively  higher  frequencies.

ABSTRACT

A small-sized audio signal reproducing apparatus for hearing reproduced audio signals with the aid of a headphone is disclosed. Digitized and compression encoded audio signals, stored in a semiconductor memory, are read out so as to undergo a decoding operation, which is an inverse operation to compression encoding, to reproduce the audio signals, and the reproduced signals are heard by the headphone. The apparatus may be significantly reduced in size and weight as compared to the apparatus in which a tape or a disk is used as the recording medium.
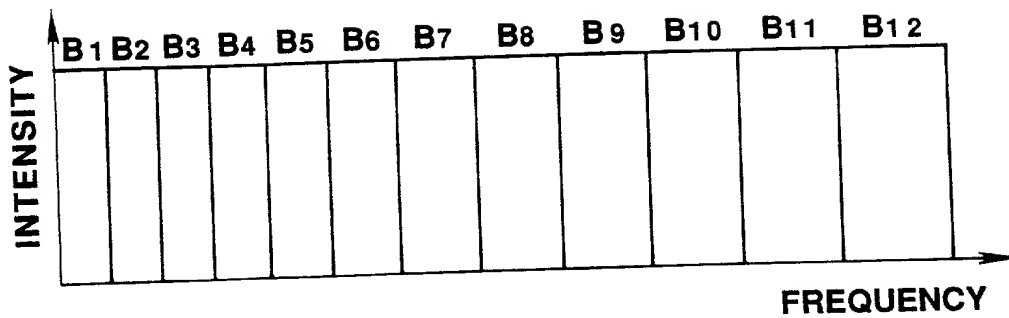
**FIG.1**

31 — ○

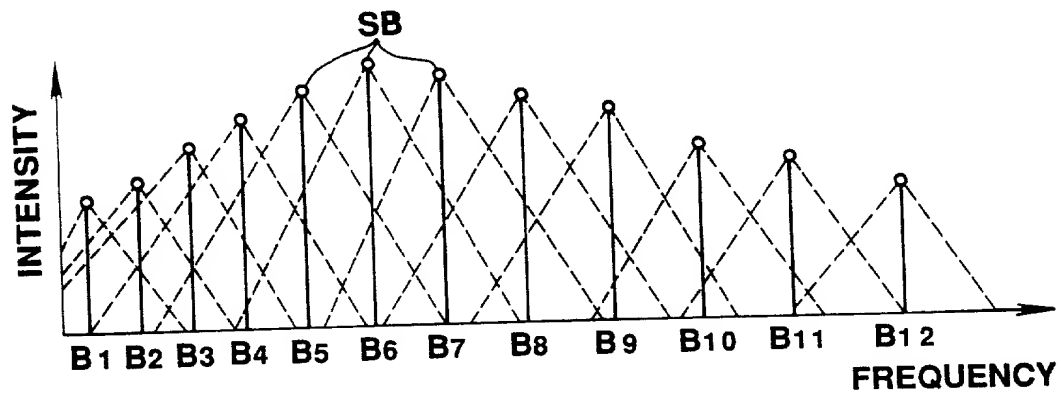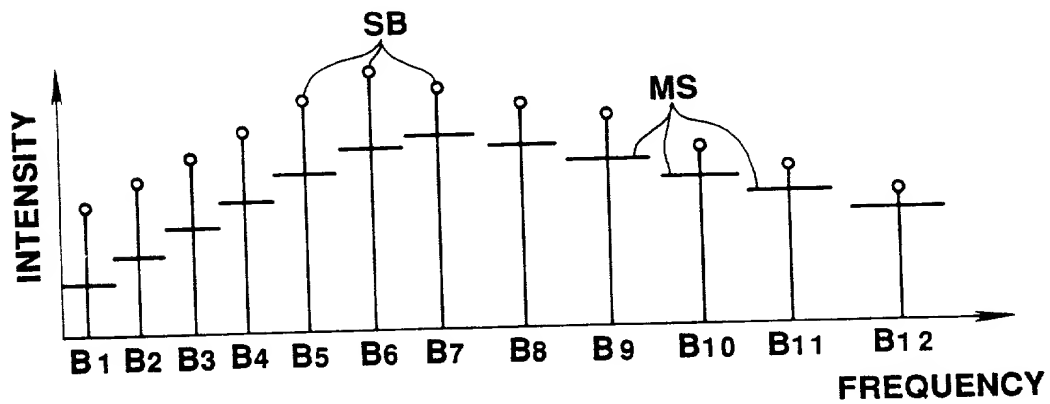32 — A/D

33 — ENCODER

40

41 — SEMICONDUCTOR MEMORY

42 — DECODER

43 — D/A

44



**FIG.2**

50

51

52L

56

53L

54L

52R

57

58

53R

54R

FIG.3

**FIG. 4**



**FIG. 5**



**FIG. 7**

101m-2  101m-1  101m  101m+1  101m+2  101m+3

$Z^{-1}$  $Z^{-1}$  $Z^{-1}$  $Z^{-1}$  $Z^{-1}$  $Z^{-1}$

102m-3  102m-2  102m-1  102m  102m+1  102m+2  102m+3

$\Sigma$  104

105

# FIG.6

B1  B2  B3  B4  B5  B6  B7  B8  B9  B10  B11  B12

INTENSITY

SS

RC

MS

FREQUENCY
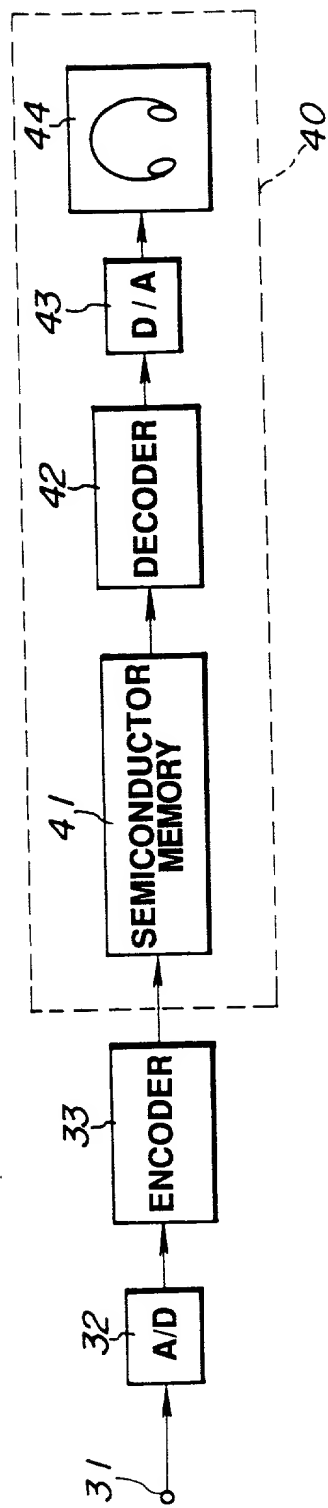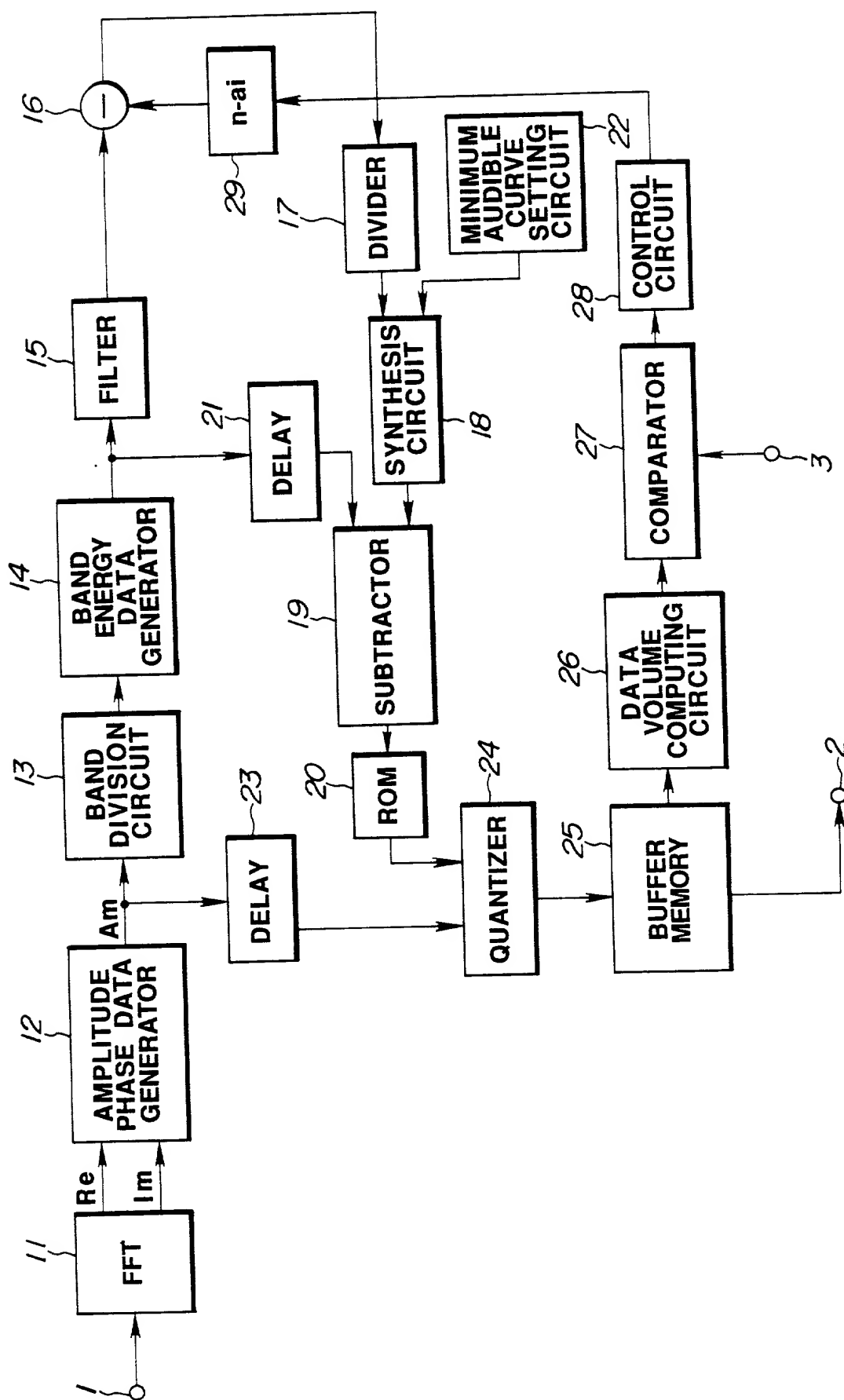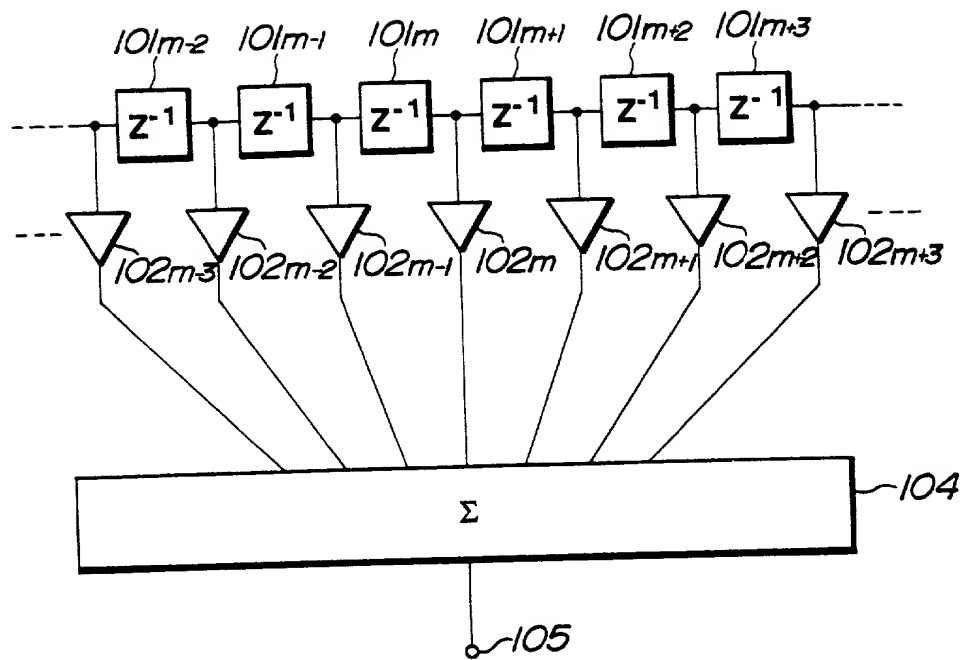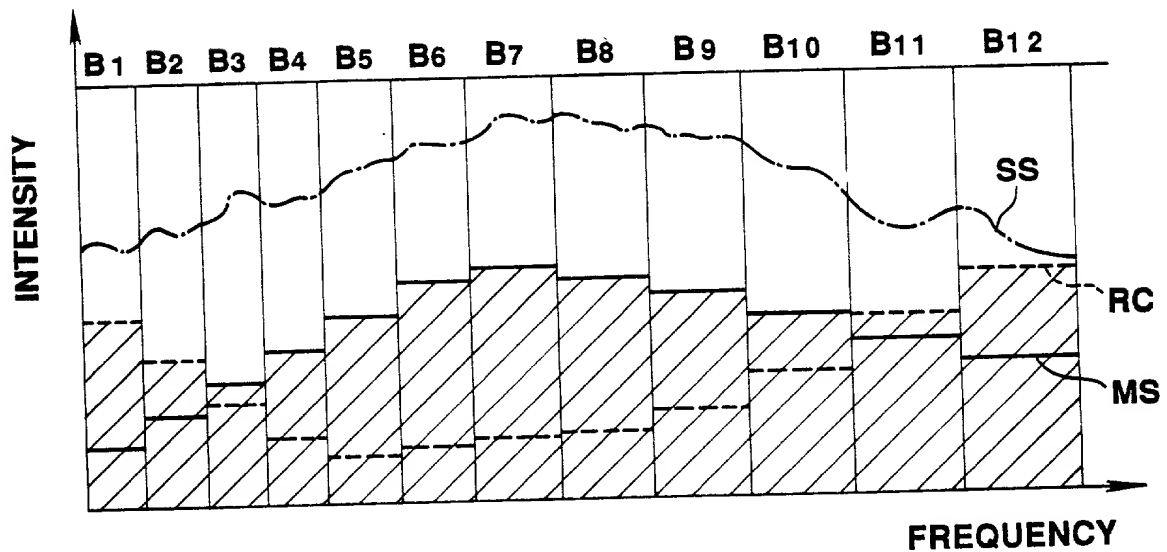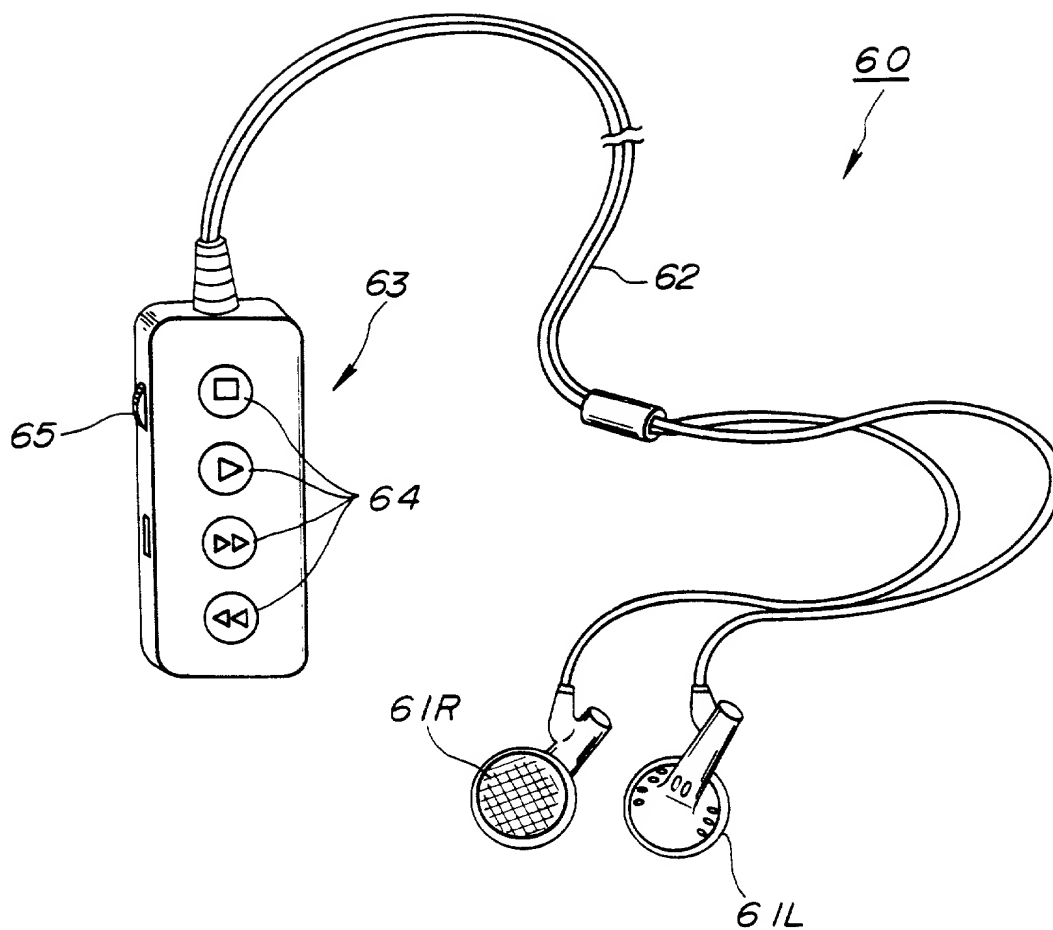
# FIG.8

**FIG.9**

# DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Audio Signal Reproducing Apparatus

the specification of which
(check one)

_____ is attached hereto.

__X__ was filed on _10/22/90_____ as

Application Serial No.__07/600,818_____

and was amended on _____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which I am aware which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

| Prior Foreign Application(s) | | | Priority Claimed | |
| Number | Country | Filing Date | Yes | No |
|--------|---------|-------------|-----|-----|
| P278209/89 | Japan | October 25, 1989 | X | |
| | | | | |
| | | | | |

I hereby claim the benefit under Title 35, United States Code, Section 120 of an United States Application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a which occurred between the filing date of the prior application and the nationa or PCT international filing date of this application:

| Application Serial No. | Filing Date | Status |
|---|---|---|
| | | |
| | | |

And I hereby appoint Lewis H. Eslinger, Reg. No. 18,558; Jay H. Maioli, Reg. No. 27,213; Donald S. Dowden, Reg. No. 20,701; Gerald W. Griffin, Reg. No. 18,886; Ivan S. Kavrukov, Reg.No. 25,161; Thomas F. Moran, Reg. No. 16,579; Christopher C. Dunham, Reg. No. 22,031; Normal H. Zivin, Reg. No. 25,385; Jules P. Kirsch, Reg. No. 20,293; John P. White, Reg. No. 28,678; Thomas G. Carulli, Reg. No. 30,616 and Robert D. Katz, Reg. No. 30,141; and each and all of them, all c/o Cooper & Dunham, 30 Rockefeller Plaza, New York, NY 101 (Tel. (212) 977-9550), my attorneys, each with full power of substitution an revocation, to receive the patent, to transact all business in the Patent an Trademark Office connected therewith and to file any International Applicati which are based thereon under the provisions of the Patent Cooperation Treat

Please address all communications, and direct all telephone calls, regardin this application to

Lewis H. Eslinger                                      Reg. No. __18,558__

Cooper & Dunham
30 Rockefeller Plaza
New York, N.Y. 10112
Tel. (212) 977-9550

I hereby declare that all statements made herein of my own knowledge are true an that all statements made on information and belief are believed to be true; an further that these statements were made with the knowledge that willful fals statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willfu false statements may jeopardize the validity of the application or any paten issued thereon.

Full name of sole or
first joint inventor ___MASAYUKI NISHIGUCHI___

Inventor's signature ___Masayuki Nishiguchi___

Citizenship ___JAPAN___          Date of signature _January 8, 199_

Residence ___KANAGAWA, JAPAN___

Post Office Address ___c/o Sony Corporaton, 7-35, Kitashinagawa___

___6-chome, Shinagawa-Ku, Tokyo, Japan___

Full name of joint
inventor (if any) _____YOSHIHITO FUJIWARA_____

Inventor's signature _____*Yoshihito Fujiwara*_____

Citizenship _____JAPAN_____ Date of signature __February 27,__
                                                                    199_

Residence _____KANAGAWA, JAPAN ,_____

Post Office Address ___c/o Sony Corporaton, 7-35, Kitashinagawa_____

_____6-chome, Shinagawa-Ku, Tokyo, Japan_____


Full name of joint
inventor (if any) _____

Inventor's signature _____

Citizenship _____ Date of signature _____

Residence _____

Post Office Address _____

_____


Full name of joint
inventor (if any) _____

Inventor's signature _____

Citizenship _____ Date of signature _____

Residence _____

Post Office Address _____

_____